MTP Observations During TexAQS 2000

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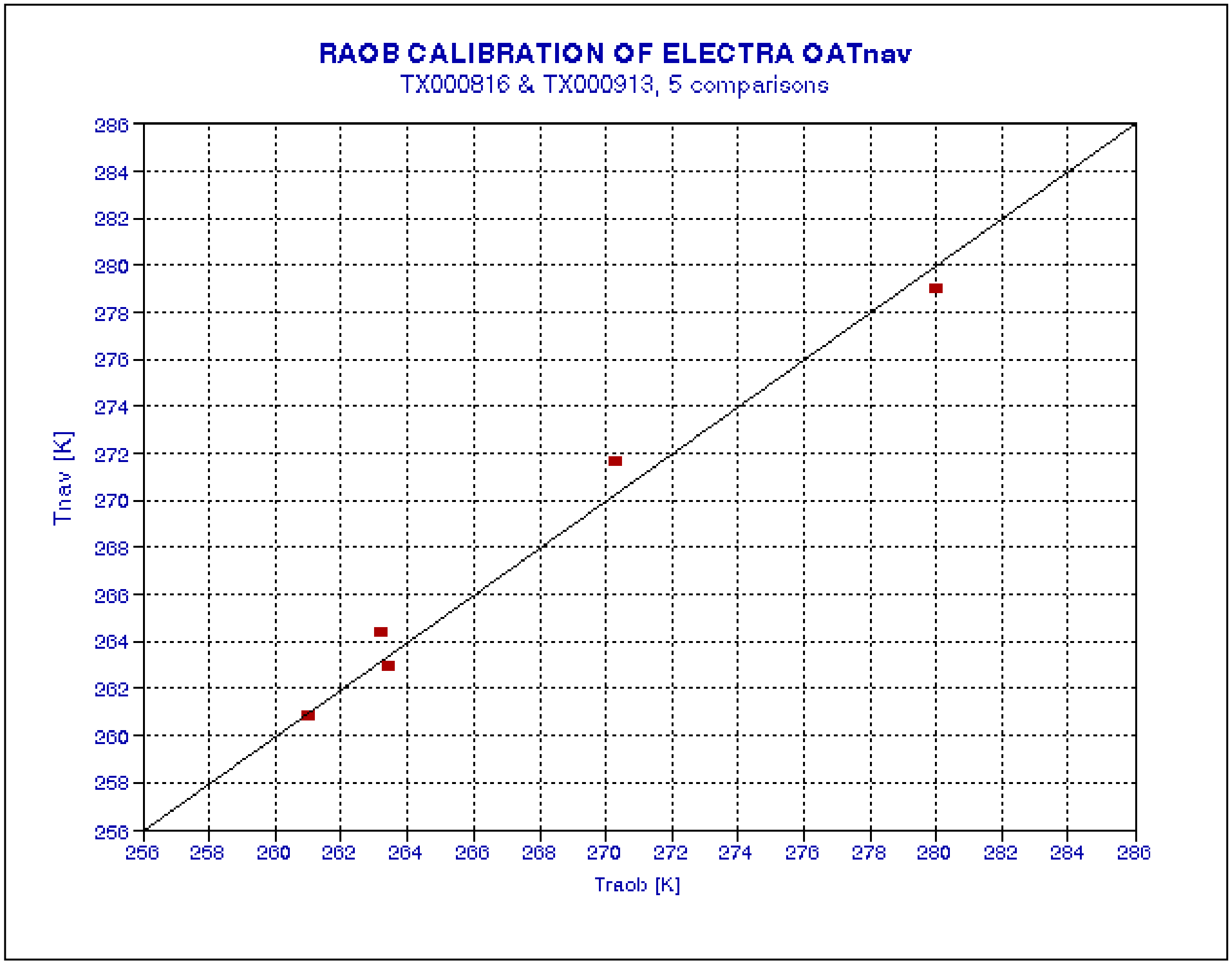
Introduction

The flights of the Jet Propulsion Laboratory (JPL) Microwave Temperature Profiler (MTP) aboard the NCAR Electra during the TexAQS 2000 campaign represented the first time that a MTP has flown extensively in the planetary boundary layer. One of the goals of the MTP measurements was to detect low level inversion layers responsible for trapping pollution. Since funding to analyze the MTP data has only recently become available, this paper will focus on the temperature calibration process, but in addition, some preliminary results will be presented.

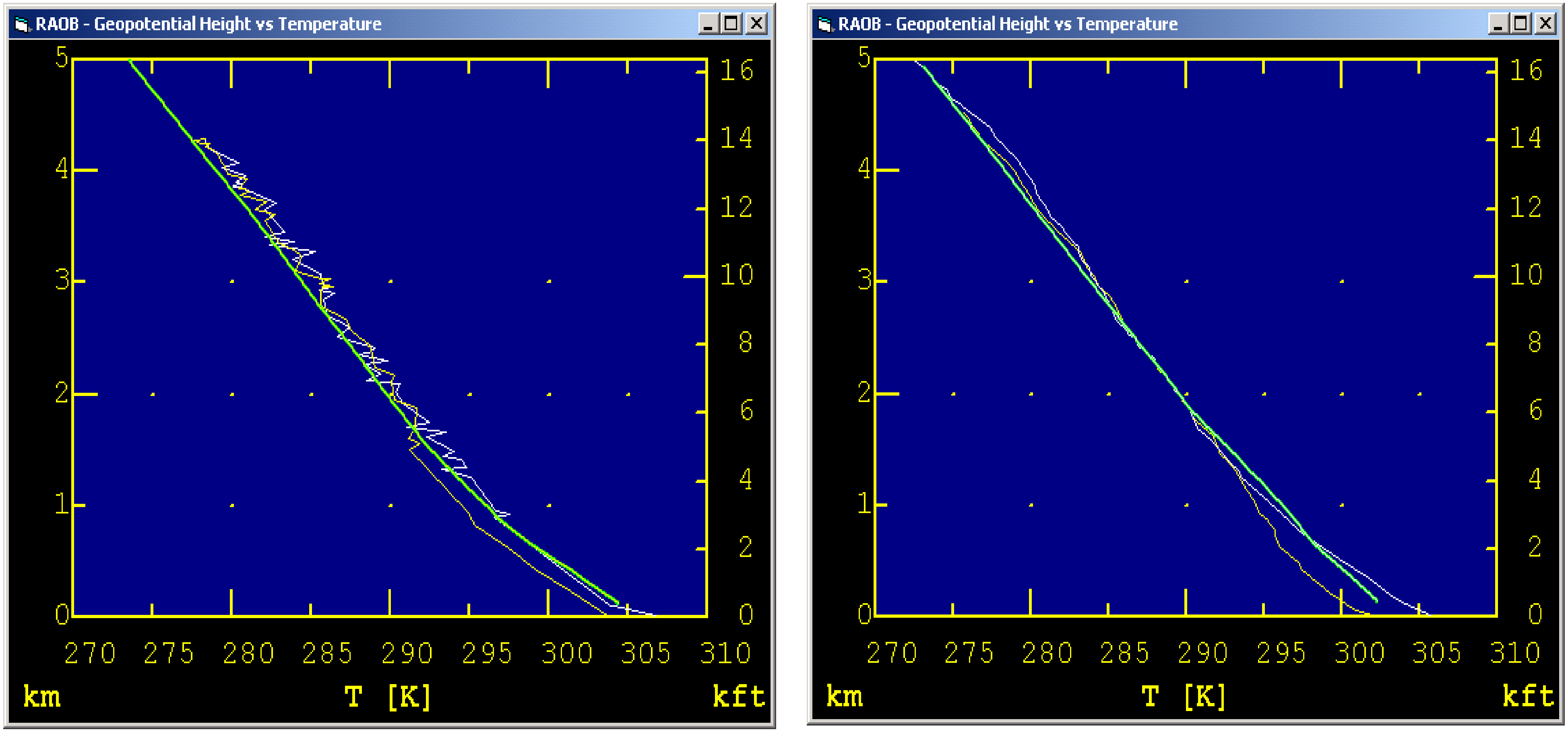
As shown in the image to the left, the MTP was located in a window just aft of the forward right-side escape door on the NCAR Electra. It measured the natural, thermal, microwave emission from oxygen molecules in the flight direction as a sensor scans from near-zenith to near-nadir. This information is used to retrieve the vertical temperature field along the flight track of an aircraft. A profile is produced every 15 seconds, which corresponds to 1 mile at an Electra speed of 216 kts.

A particular challenge to interpreting the data is the effect of ground emission on the downward looking measurements. This is because retrieval coeff-icients are calculated using radiosondes, and the lowest radiosonde level does not reflect the actual temper-ature seen by the instru-ment. We investigated the use of the infrared surface-temperature measurements from the NCAR Electra Heimann probes to constrain our retrievals, but these are not useable over land because the emissivity causes the temperature to change by up to 25 K per second. As a result, we used optical depth information to weight the measurements so as to avoid ground contamination. This work is being refined, but is producing excellent results.

Temperature Calibration

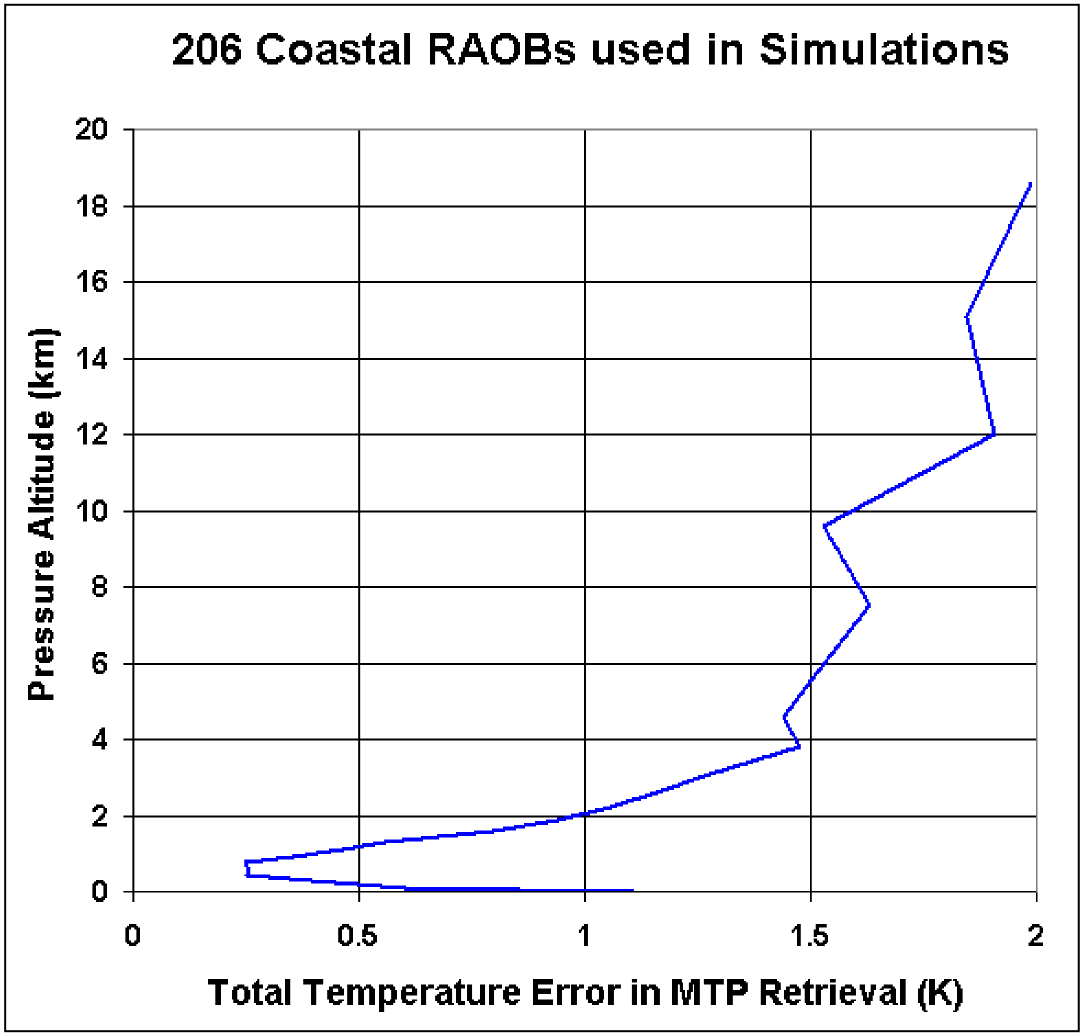


MTP measurements are usually calibrated against radiosondes by spatially and temporally interpolating to the aircraft location. If possible, we use outside air temperature (OAT) measurements to transfer the calibration. For TexAQS 2000, we used the two transit flights to compare the NCAR Electra temperature measurements (Tnav) to radiosondes (Traob). This was done because we were concerned that our downward-looking measurements, if not at the highest available altitudes, might be contaminated by ground radiation. As shown in the fit above, Tnav – Traob = +0.22 +/- 0.47 K, the agreement between Tnav and Traob is excellent.



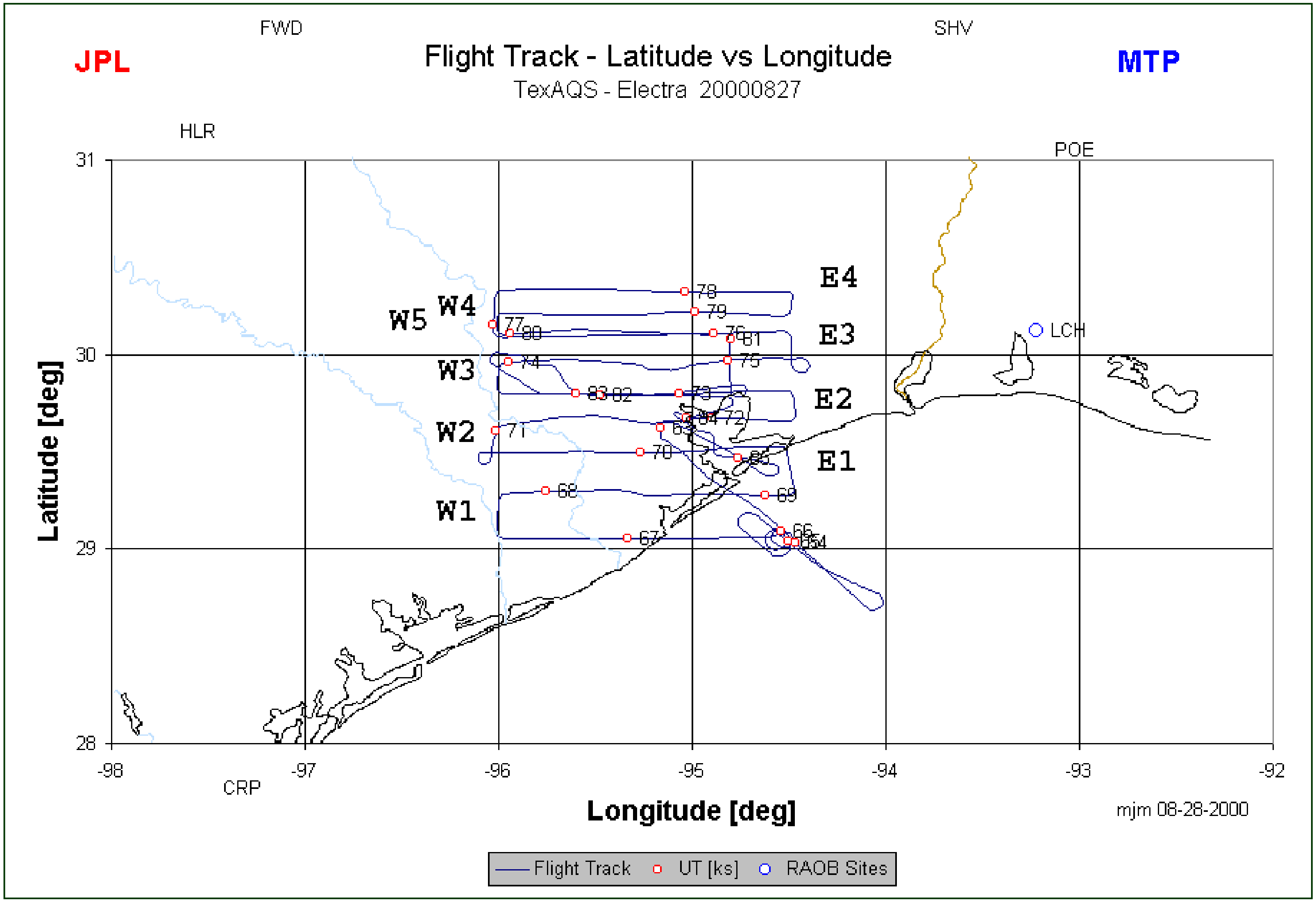
A comparison of MTP retrieved temperature profiles (green) with PNNL radiosondes launched from downtown Houston (white) and La Marque (yellow) on August 25, 2000. The left panel is for 19:56 UTC and the right panel for 23:00 UTC. In each panel, the ordinate is the geopotential height in km (left side) and kft (right side). The abscissa is temperature in Kelvin. Understandably, the La Marque radiosondes are cooler than those from downtown Houston in the PBL. The MTP profiles were not co-located with the radiosonde launch sites.

Retrieval Accuracy Simulation

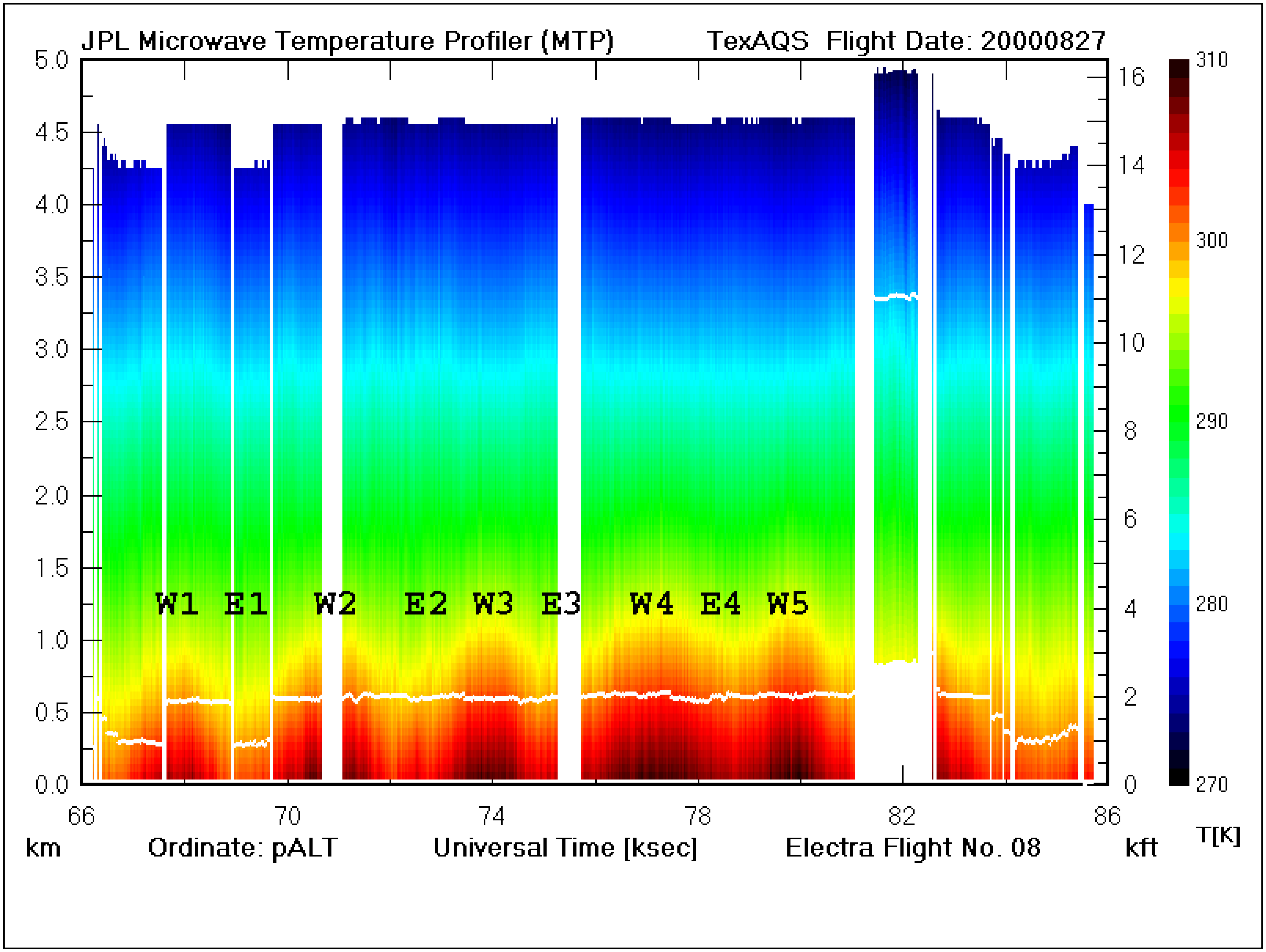


The figure to the left shows the result of using 206 radiosondes from BRO, CRP, LCH, SIL, and the PNNL sondes, to solve the forward radiative transfer problem, and then performing the inverse calculation on these data to assess the accuracy of the retrieval. The simulation was done for a flight altitude of 2000 feet (0.6 km), which was typical for the Electra. The retrieval accuracy was <1 K from the surface to 2 km, being best at flight altitude (0.25 K). The error degrades slowly to 2 K at ~19 km. Based on past experience, we would have expected better performance above the aircraft. The reason for the degraded performance is that the observing frequencies where chosen for flight at 10-12 km. For PBL measurements, better frequencies could have been chosen.

Horizontal Temperature Gradients



On August 27, 2000, the Electra flew east-west tracks over Houston. The labels W1, E1, … correspond to times on the temperature curtain

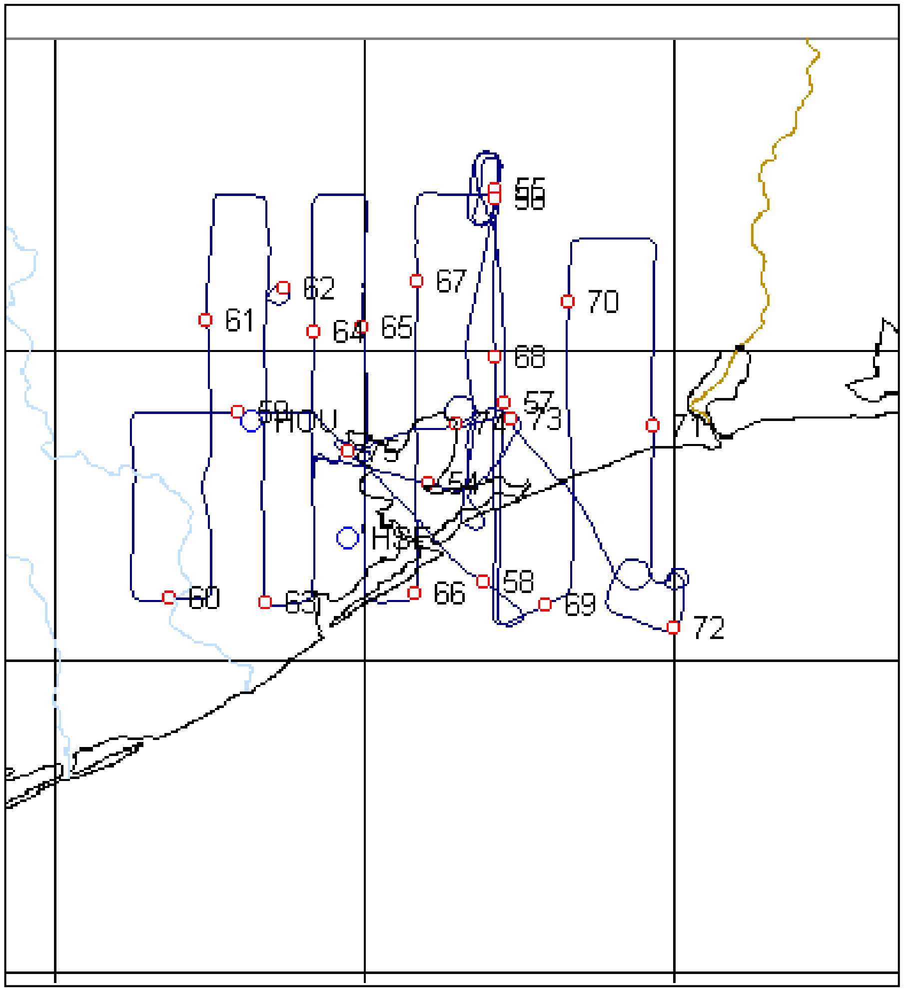


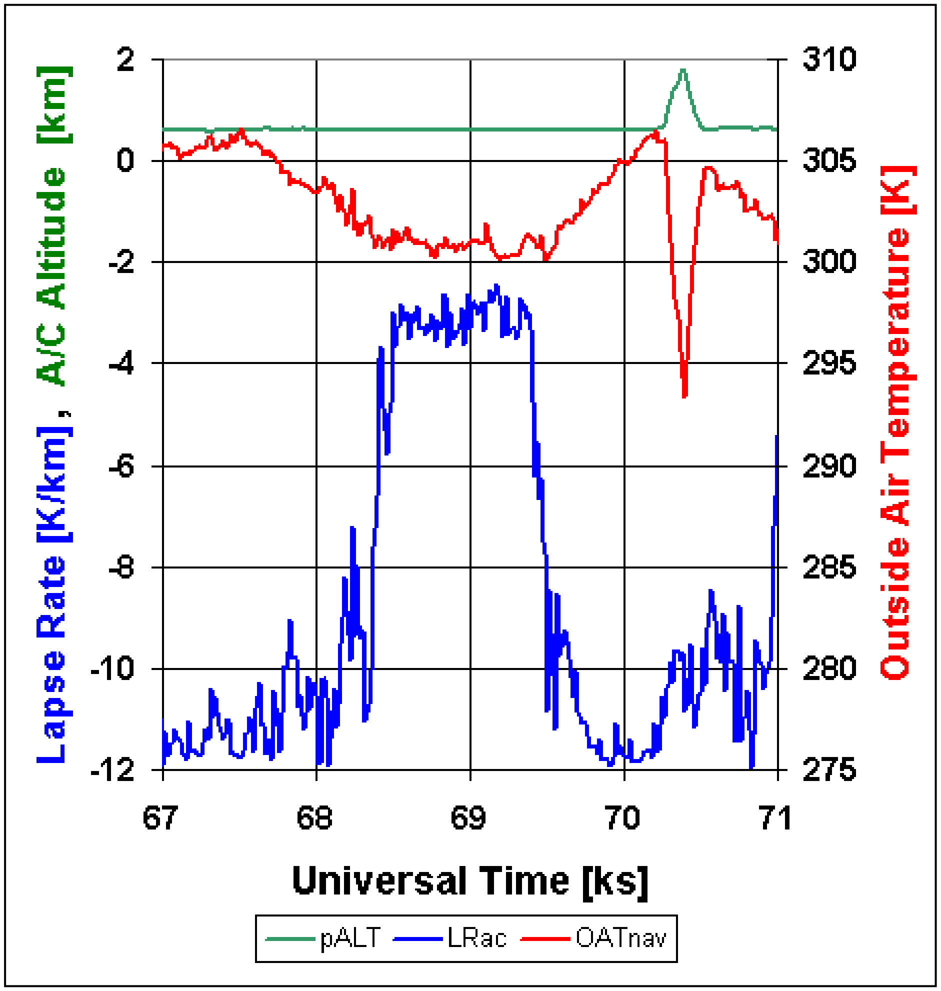
illustrated above. The white trace is the Electra pressure altitude, which was 2000 feet for most of the flight (right ordinate). The east-west gradient was ~3 K at altitudes below ~5000 feet, and negligible above 5000 feet.

An even more dramatic example of large temperature gradients is provided by the NCAR Electra flight of September 1, 2000, when it was flying tracks with a north-south orientation.

Referring to the figures to the right, in the flight segment between 67-71 ks UTC, the Electra was furthest north at 67.5 ks and 70.2 ks, and furthest south at 68.9 ks. It crossed the coastline at ~68.6 ks heading south and ~69.5 ks heading north. At this time there is a dramatic change in the lapse rate from being super-adiabatic over land to –3 K/km over water. (The lapse rate is calculated through a 1-km thick layer centered on the aircraft.)

Also, during the north-south flight tracks, there is nearly a 6 K change in temperature at constant flight level (2000 feet), being 306 K when furthest north and 300-301 K when over water.



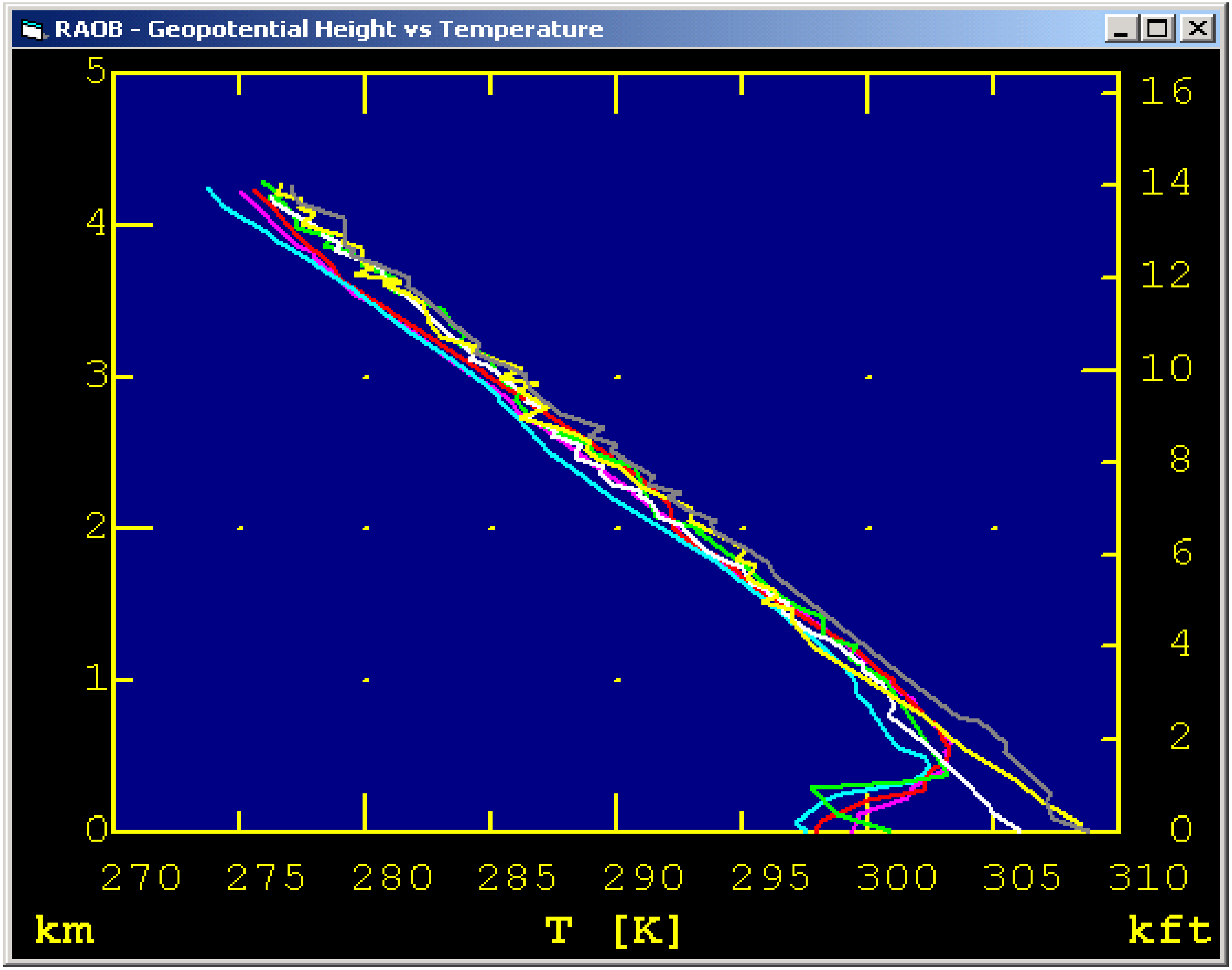


Left Panel: NCAR Electra flight track over Houston on September 1, 2000. Red circles on flight track indicate the current UTC kilo-seconds. *Right Panel:* Outside Air Temperature (K), Lapse Rate (K/km), and Electra Pressure Altitude (km) for flight segment between 67-71 ks UTC.

Inversion Layers

One of the goals of the MTP observations was to measure low level inversions. Although all the MTP data is not yet analyzed, it is unlikely that any inversions will be seen. The PNNL radiosonde data was examined for inversions during the Electra flight time, and only three were found – all over the downtown Houston launch site. (102 of the 208 PNNL radiosondes were launched while the Electra was airborne.)

The figure below uses PNNL radiosonde data to show the diurnal variation of temperature profiles for August 31, 2000, at La Marque. The UTC launch times were 0501 (pink), 0758 (red), 1106 (light blue), 1401 (green), 1700 (white), 2000 (yellow) and 2300 (grey). It is clear that ground-level nighttime inversion vanishes between 1401 and 1700 UTC, and reappears after 2300 UTC. Since all but one Electra take off was before 1600 UTC, and all but two landings were after 2300 UTC, it is unlikely that the Electra would have encountered any inversions.



Diurnal variation of the ground-level night-time inversion based on PNNL radiosonde launches on August 31, 2000, at La Marque, Texas.

Summary

Although the Microwave Temperature Profiler (MTP) data obtained while flying on the NCAR Electra during TexAQS 2000 is still in an early stage of analysis, it is clear that it will be able to accurately assess the vertical temperature field in the planetary boundary layer. This conclusion is based upon comparisons with PNNL radiosonde data and from simulations.

The MTP data should be very useful for studying the mesoscale temperature field during TexAQS 2000, including the vertical and horizontal variability of temperature and lapse rate, and how they agree with models. We look forward to working with meteorologists and modelers in using and interpreting the MTP data.

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